FORMALDEHYDE DISINFECTION WITH SPECIAL REFERENCE TO THE COMPARATIVE VALUE OF SOME OF THE PROPRIETARY PRODUCTS.*

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AT a recent meeting of the American Public Health Association, B. R. Rickards[1] reported the result of an investigation of the methods of disinfection employed in the larger cities of the United States. He had sent a circular letter to every city of over 100,000 and received replies from 29 cities. The methods employed in these cities were as follows:

Formaldehyde generators		9
Generators alone	5	
Combined with other methods	4	
Permanganate-formalin method		12
Permanganate method alone	9	
Combined with other methods	3	
Solidified formaldehyde		9
(proprietary articles sold under various names)		
Solidified formaldehyde alone	4	
Combined with other methods	5	
Formalin sheet spraying method		4
Sheet spraying alone	2	
Combined with other methods	2	
Formalin-aluminum-sulphate-lime		1
Sulphur		2
Sulphur alone	1	
Combined with other methods	1	

The time of exposure varied from 3 to 24 hours, the majority requiring 6 to 8 hours. All advised sealing the rooms. Seven cities appreciated the value of moisture. One did not deem it advisable. Seventeen cities tested the result of disinfection by exposing cultures in the rooms. Nine bought their formaldehyde on analysis. The amount of formaldehyde used per 1,000 cu. ft. varied from 1 oz. of the solid product to 32 oz. of formalin.

In commenting on these figures, Rickards calls attention to "the large number which use the solid proprietary forms about which they evidently know little except what the agent has told them," and says

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[1] *Amer. Jour. Public Hygiene*, 1909, 19, p. 367.

further: "One fact stands out strikingly: each city is proceeding on a go-as-you-please policy, adopting that method which happens to suit the immediate situation best from a standpoint of convenience and expense, regardless usually of the question of efficiency." "The present situation is intolerable viewed from a scientific standpoint. If disinfection is of value in any case, then it should be done in an efficient manner; a manner proved by exhaustive work to be reliable. If disinfection in general is not of value and can be proved to be of little or no value in any given disease, then disinfection in that case should be abandoned and trouble and expense thus saved."

These statements from such eminent authority we believe show fully the necessity for our investigations. If disinfection is "farcical" in the cities investigated by Rickards, then disinfection is farcical in numerous other localities and a revision of the methods recommended by many of the boards of health is distinctly indicated.

In 1906 Daniel Base[1] published the results of a series of experiments performed in the Division of Pharmacology, Hygienic Laboratory, U.S. Public Health and Marine Hospital Service, for the purpose of determining the yield of formaldehyde in various methods of liberating the gas for the disinfection of rooms. These experiments were performed with a room containing 2,000 cu. ft. of space. The room was lined on the sides and ceiling, as well as the floor, with sheet zinc to prevent condensation of the gas upon the surfaces. From these experiments based upon the quantity of gas recovered from the air in the room, the various methods investigated were arranged as follows:

1.	Trenner Lee retort	47 per cent
2.	Autoclave	41.5 "
3.	Permanganate-formalin (1–2)	39.15 "
4.	Diluted formaldehyde-permanganate	35.1 "
5.	Sheet spraying	30.48 "
6.	Formalin-aluminum-sulphate-lime	14 "

The high authority of these investigators has left very little room for argument regarding the comparative value of the methods mentioned, but it will be observed that the experimenters did not give any comparative results with the various proprietary forms of solidified formaldehyde now on the market; and it was essentially for the

[1] *Jour. Amer. Chem. Soc.*, 1906, 28, p. 964.

purpose of comparing these with formalin that our experiments have been undertaken.

Since we did not have at our disposal a zinc lined room and were obliged to employ a room with papered walls and ceiling and wooden floors, the average quantity of gas recovered from the air was necessarily somewhat lower than that obtained by Daniel Base. This was because of the marked condensation of formaldehyde upon the various surfaces. Von Bronn[1] in 1899 made experiments charging an ordinary living room well sealed, with known quantities of formaldehyde. He made three determinations, and the highest percentage of the original formaldehyde charged into the room obtained from the air was 16.94 per cent. The remainder of the formaldehyde was found to have condensed on the exposed surfaces. From these results he concluded: "It can be said that the greatest portion of the liberated formaldehyde is condensed at once on the surface of the walls and on the objects in the room. Accordingly the idea that in disinfection the formaldehyde acts as a gas, needs correction. The more experiments have been made with formaldehyde, the more has it been observed that its maximum germicidal effect can only be obtained in the presence of an abundance of water vapor. Therefore, it appears that by vaporizing formaldehyde, we only accomplish a uniform distribution of the disinfectant in space, but that the real efficiency lies not in the formaldehyde gas but in the solution which condenses everywhere on surfaces." The observations of von Brunn have been repeatedly confirmed by other experimenters, but it has been further observed that the percentage of gas recovered from the air in a given room charged with formaldehyde under the same conditions is fairly constant for different quantities and may be employed in estimating the comparative value of the different methods of charging a room.

The room at our disposal measured 19 ft. × 12½ ft. × 12½ ft., having two doors and one window. The walls and ceiling were papered, the floor being of hard wood. The window and one of the doors were carefully sealed with paper. The other door was padded with cloth on all its edges so that when closed it would be as tight as any ordinary room could be made for practical disinfection. The capacity

[1] *Ztschr. f. Hyg.*, 1899, 30, p. 201.

of the room was about 2,965 cu. ft., but in order to give the benefit of all doubt to the various manufacturers and for the purpose of convenience, the room was regarded in all our experiments and calculations as containing 3,000 cu. ft. of space.

TABLE 1.

THE AMOUNT OF FORMALDEHYDE ABSORBED AND THE AMOUNT REMAINING IN THE AIR AT VARYING PERIODS AFTER CHARGING THE ROOM.

Number	Temperature ° C.	Percentage of Humidity	Wind Miles	Formaldehyde Product Used per 1,000 Cu. Ft.	Percentage of Strength of Formaldehyde	Method of Liberation	Time Since Starting	Time Required to Draw Air	Liters of Air Drawn	Absolute Formaldehyde Used per 1,000 Cu. Ft. in Gm.	Absorption per Sq. Ft. of Surface in Mgm.		Absolute Formaldehyde Found per Cu. Ft. of Space in Mgm.	Percentage of Yield
											Moist	Dry		
12	18	85	1	330 c.c. Water 270 c.c.	37.8	$KMnO_4$ 330 gm.	10 m.	15 m.	5	125	...	...	32.30	25.90
							1 hr.	1 hr.	20		...	...	16.15	12.96
							3 hrs.	30 m.	10		...	...	12.32	9.86
							5 "	.....	..		52	23	.....	... .
11	19	73	4	330 c.c. Water 270 c.c.	37.8	$KMnO_4$ 330 gm.	10 m.	15 m.	5	125	...	...	32.30	25.90
							30 "	.....	..		343	37	.....	.....
							1 hr.	1 hr.	20		...	...	15.92	12.77
							2 hrs.	.....	..		147	33	.....	.....
							3 hrs.	30 m.	10		56	33	10.62	8.51
							5 "	.....	..		35	30	.....	.....
							24 "	.....	..		19	12	.....	.....
14	21	75	1	300 c.c.	37.8	$KMnO_4$ 210 gm.	10 m.	15 m.	5	113	234	21	43.31	38.23
							30 "	.....	..		450	35	.....	.....
							1 hr.	1 hr.	20		...	...	22.50	19.86
							2 hrs.	.....	..		160	33	.....	.....
							3 "	30 m.	10		83	28	17.41	15.30
							5 "	.....	..		45	27	.....	.....
							24 "	.....	..		22	21	.....	.....
9	21	75	6	300 c.c.	37.8	$KMnO_4$ 150 gm.	10 m.	15 m.	5	113	197	12	45.01	39.70
							30 "	.....	..		399	22	.....	.....
							1 hr.	1 hr.	20		...	...	22.08	19.50
							2 hrs.	.....	..		163	27	.....	.....
							3 "	30 m.	10		72	24	17.41	15.30
							5 "	.....	..		39	24	.....	.....
							6 "	30 m.	10		...	...	14.01	12.30
23	20	81	4	104 gm. (Solid)	62	Parrafin Candle (DePree)	45 m.	15 m.	5	64	303	12	30.57	47.50
							1 hr.	1 hr.	20		225	24	22.52	35.00
							2 "	.....	..		168	26	.....	.....
							3 "	30 m.	10		75	25	13.60	21.20
							6 "	30 "	10		40	19	11.46	17.80

In comparing the relative value of the different methods of charging the room with formaldehyde, the following points have been considered: (1) the amount of formaldehyde in the air of the room; (2) absorption on moist and dry surfaces; (3) effect on cultures.

Since there is considerable variation in the time required to liberate the formaldehyde by the various methods, an attempt was made to

select an arbitrary time which would insure complete liberation of all the gas before any of the air was drawn for analysis. After a room is charged, the percentage of formaldehyde gas in the air diminishes rather rapidly and the results will be materially lower if the air is drawn some time after charging.

The results show that during the first hour after liberation the amount of gas in the air rapidly diminishes, while at the same time the absorption on dry paper increases. The moist paper shows its highest absorption after 30 minutes, after which the formaldehyde is rapidly lost. This is due to the evaporation of the moisture. After two hours there is a uniform diminution in the amount contained in the air as well as in the dry paper which indicates the rate of leakage.

With one exception, air was drawn in all our experiments, beginning exactly one hour after the charging was begun. This of course favors those preparations which require the longest time to liberate their gas and in comparing results this should be considered.

THE AMOUNT OF FORMALDEHYDE IN THE AIR OF THE ROOM.

After a series of preliminary experiments in which potassium cyanide and iodate solutions were tried for absorbing the gas, it was decided to abandon both and use distilled water. The formaldehyde was absorbed in four 100 c.c. flasks, each containing 50 c.c. of distilled water. The amount of formaldehyde was determined separately in these flasks after the desired quantity of air from the room had been drawn through. Practically all of the formaldehyde was found each time in the first flask and only a small amount in the second. The third and fourth flasks never contained measurable quantities and for practical purposes could, we believe, have been discarded.

The air was drawn from the charged room through a hole in the door which was fitted with a perforated cork stopper through which a glass tube projected about 18 inches into the room. The air was measured by displacement of water in a bottle graduated from the top. All connections and stoppers were rubber and each time before drawing air, clamp No. 1 was closed and clamp No. 2 opened to insure against all leaks. After drawing the air, the flasks were at once disconnected and an accurately measured quantity of $\frac{n}{10}$ iodine added to each one. This was followed by $\frac{n}{1}$ sodium hydroxide, using 1 c.c. $\frac{n}{1}$ NaOH for every 5 c.c. $\frac{n}{10}$ iodine. This was allowed to stand

for about 15 minutes in order to complete the reaction which takes place essentially as follows:

$$I_2 - CH_2O - 2NaOH = CH_2O_2 - 2NaI - H_2O.$$

After 15 minutes, $\frac{N}{1}$ H_2SO_4 in slight excess was run in to liberate the uncombined iodine which was determined by means of $\frac{N}{10}$ sodium thiosulphate using starch indicator. From this titration the number of c.c. of $\frac{N}{10}$ iodine absorbed multiplied by 0.0015 gives the weight of absolute formaldehyde present in the amount of air drawn.

Example: Volume of air drawn -20 liters

Amount of $\frac{N}{10}$ iodine absorbed -6 c.c.

$\frac{6 \times 0.0015}{20}$ = gm. CH_2O in 1 liter

One cubic foot is 28.315 liters

$\frac{6 \times 0.0015}{20.} \times 28.315 = 0.01274$ gm. per cu. ft.

ABSORPTION ON MOIST AND DRY SURFACES.

For determining absorption, Swedish filter papers diam. 9 cm. were used. These were suspended from strings near the sides of the room. The dry papers were taken directly from the package in the laboratory. The moist papers were dipped in distilled water immediately before starting the experiment. These moist papers when removed after five hours were always apparently dry. Nevertheless, the amount of formaldehyde they contained was invariably higher than the amount contained in the dry paper, and the excess of formaldehyde on an average day was probably proportionate to the moisture retained. The absorption was determined after five hours except where otherwise stated.

EFFECT ON CULTURES.

The effect of the various preparations on cultures may best be taken up under three different heads: (*a*) effect on different species; (*b*) time required to kill; (*c*) penetrating power. For the effect on different species, we used staphylococci—obtained from an abscess; streptococci—obtained from throat culture; B. coli—isolated from feces; B. diphtheria—obtained from throat culture; B. typhosus—obtained from Parke, Davis & Co.; B. anthracis—obtained from Parke, Davis & Co. All test cultures were grown in +1 broth 48 hours at 37° C., after which time silk threads about an inch in

length previously sterilized at 160° C. for one hour were dipped in the growth and dried in an incubator at 37° C. for 16 to 18 hours. In the various experiments, "dry cultures" applies to such contaminated threads coming from the incubator and "moist cultures" refers to these same threads moistened with sterile distilled water immediately before charging the room.

The formaldehyde was always liberated in the center of the room and these cultures were suspended by means of an aluminum wire on strings drawn across the room midway between the generators and the wall.

In order to determine the "time required to kill," a string was extended across the room, in position similar to those already described, from a large hole in the door. This string was passed over a pulley at the opposite side and returned, being held in place by a tightly fitting cork. On this string were tied cultures of B. coli which could easily be drawn out one at a time at desired intervals.

Penetrating power was determined by placing layers of common sheeting, after boiling to remove the starch, one above the other. This package was covered on the sides, bottom, and one end with heavy wrapping paper, in which condition it was sterilized in the hot air oven each time before using. Dry cultures were placed between the various layers after which the open end was sealed with paper. This prevented absolutely any formaldehyde from reaching the cultures except as it passed through the various layers of sheeting. After exposure, the threads were placed in sterile +1 broth and incubated for 96 hours at 37° C. except the colon cultures which had been used to determine "time required to kill." These were grown in lactose broth in Smith's fermentation tubes where the organisms could be easily identified and accidental contamination excluded. The following form shows a record of the routine observations made in connection with each experiment.

EXPERIMENT NO. 3.

PERMANGANATE-FORMALIN METHOD. 2 OZ. FORMALIN PER 1,000 CU. FT.

Formalin, 37.8 per cent, 180 c.c.
Permanganate, 90 gm.
Capacity of room, 3,000 cu. ft.
Temperature, 18° C. Humidity, 76. Wind, 8 miles.

Time for reaction, 5 min. Air drawn 1 hr. after starting.
Amount of air drawn, 20 liters. Time, 1 hr.
Amount of absolute formaldehyde used, 68 gm.
Absorption per sq. ft. of surface { Moist, 14.62 mgm. / Dry, 5.62 mgm.
Amount of formaldehyde found in air { per cu. ft. 2.97 mgm. / entire room, 8.91 gm.
Percentage of formaldehyde recovered from air, 13.17 per cent.

CULTURAL RESULTS.

48 HR. CULTURES EXPOSED 5 HRS. INCUBATION 96 HRS.

(+=growth; o=no growth.)

ORGANISMS	MOIST			DRY			CONTROL
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	
Staphylococci	o	o	o	+	+	+	+
Streptococci	o	o	o	+	+	+	+
B. coli	o	o	o	+	+	+	+
B. diphtheriae	o	o	o	+	+	+	+
B. typhosus	o	o	o	+	+	+	+
B. anthracis	o	o	o	+	+	+	+

Culture		15 M.	30 M.	1 Hr.	2 Hrs.	3 Hrs.	4 Hrs.	5 Hrs.	
B. coli	Moist	+	o	o	o	o	o	o	growth
		20%	o	o	o	o	o	o	gas
	Dry	+	+	+	+	+	+	+	growth
		25%	30%	20%	15%	30%	40%	35%	gas

B. coli Penetration	Dry	1	2	3	4	5	6	7	8	9	10	11	12	15	
		+	+	+	+	+	+	+	+	+	+	+	+	+	Exposure 5 hrs.

THE PERMANGANATE-FORMALIN METHOD.

When formalin and potassium permanganate are brought together a vigorous reaction takes place, liberating sufficient heat to volatilize a large quantity of formaldehyde gas and water. This reaction begins from 30 to 50 seconds after the ordinary potassium permanganate crystals and formalin are mixt, and rapidly goes on to a strong ebullition which continues until all of the permanganate is reduced or all of the liquid evaporated, which usually requires about five to seven minutes. During the reaction a considerable proportion of the formaldehyde is destroyed by the action of the permanganate, which probably reacts essentially as follows:

$$4KMnO_4 - 3HCOH - H_2O = 4MnO(OH)_2 - 2K_2CO_3 - CO_2.$$

Various experimenters have adopted different proportions of permanganate and formalin in view of obtaining the highest percentage of gas. Evans and Russell[1] recommended $3\frac{3}{4}$ oz. of potassium permanganate to 10 oz. of formalin, but later increased the permanganate to at least $4\frac{3}{4}$ oz. Base and McClintic recommend 5 oz. of potassium permanganate to 10 oz. of formalin. The Bureau of Animal Industry recommended about 8 oz. of potassium permanganate to 10 oz. of formalin. Hill[2] and Roberts recommend seven parts by weight of permanganate to 10 parts by volume of formalin. In choosing from these various formulae, there are two important points for consideration, viz., the amount of absolute formaldehyde available for disinfection and the relative price of the substances employed. A series of experiments was carried out to determine the value of the various proportions with results as follows:

	Formula	Amount Destroyed in Reaction	Amount Remaining in Residue after 30 Min.	Amount Available for Disinfection
1.	Formalin 10, Permanganate 7	30 per cent	3 per cent	67 per cent
2.	Formalin 10, Permanganate 5	22 " "	20 " "	58 " "
3.	Formalin 10, Permanganate $3\frac{1}{3}$	15 " "	45 " "	40 " "
4.	Formalin 10, Permanganate $2\frac{1}{2}$	11 " "	59 " "	30 " "

The amount of formaldehyde destroyed during the reaction is practically proportionate to the amount of permanganate used, up to certain limits. When the permanganate is increased above the proportion of 7 to 10 the amount of destruction is not proportionate because the heat of the reaction will drive off the formaldehyde before all of the permanganate is reduced. The amount remaining in residue increases very rapidly as the permanganate is decreased and this increase is far from being compensated by the lessened destruction. An increase in the permanganate above the 7 to 10 proportion is not be recommended, for the relative price of permanganate makes further increase uneconomical.

All of the available formaldehyde is not in reality given off in 30 minutes with the lower proportions of permanganate, and in examining residues when using the 1–2 formula after five hours usually

[1] *Fourteenth Report of the State Board of Health of Maine*, 1906, p. 227.

[2] *Amer. Jour. Pub. Hyg.*, 1909, 19, p. 576.

only 5 to 7 per cent of the original formaldehyde is found to remain, and after 24 hours only about 1 per cent. The gas which is given off after 30 minutes, however, is by slow evaporation and has practically no value for disinfection because the rate of leakage from the average room is far greater than such slow evaporation can replace.

Some have recommended various dilutions of the formalin with water for the purpose of increasing the relative humidity. It is a well-known fact that moisture greatly increases the efficiency of formaldehyde as a germicide and when the natural humidity is low and artificial moisture cannot be readily otherwise supplied, this method is to be recommended. In using permanganate-diluted-formalin, two general rules should always be borne in mind: (1) the quantity of permanganate by weight must be at least one-half as much as the entire quantity of liquid by volume; (2) the amount of additional formaldehyde destroyed is proportionate to the increase in the permanganate.

If less permanganate is used than required in Rule I, too large a proportion of the formaldehyde will remain in the residue. If too large a proportion of water be added to the formalin, a proportionate increase of the permanganate is necessary in order to volatilize it and a corresponding destruction of formaldehyde results. Thus if we were to employ a formula like this:

Formalin	10 c.c.
Water	40 "
Permanganate	25 gm.

a fairly dry residue will be obtained, but practically all of the formaldehyde is destroyed.

One of the best formulae for permanganate-diluted-formalin we have seen is that proposed by Hill[1] and Roberts, which is

Formalin	11	parts by volume
Permanganate	11	" " weight
Water	9	" " volume

According to this proportion about 45 per cent of the formaldehyde is destroyed and 5 to 7 per cent left in the residue after 30 minutes, leaving practically 48 to 50 per cent of the formaldehyde available for disinfection in the presence of an abundance of moisture.

[1] *Loc. cit.*

TABLE 2.

EXPERIMENTS WITH THE PERMANGANATE-FORMALIN METHOD.

Experiment Number	Amount Used per 1,000 Cu. Ft.		Temperature ° C.	Humidity Percentage	Amount of Formaldehyde in Mgm. Found per Cu. Ft. of Air Space	Cultural Results: + = Growth, o = No Growth, — = Not Killed in 5 Hrs. — 48 Hr. Cultures, Exposed 5 Hrs. Incubation 96 Hrs. Number of Each Exposed, 3 Moist and 3 Dry													B. coli First Culture Killed		Penetration B. coli Dry Culture
	Formalin, Ounces	Permanganate, Ounces				Staphylococci		Streptococci		B. coli		B. diphtheria		B. typhosus		B. anthracis		Control			
						Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Dry	Moist	Dry	1. Exposure 5 hrs. 2. " 7 " 3. " 24 "
I.......	½	¼	17	85	85	3+	3+	1+	3+	3+	3+	2+	3+	o	3+	2+	3+	+	—	—	1. None killed
II.......	1	½	20	66	1.48	2+	3+	1+	3+	3+	3+	1+	3+	o	3+	o	3+	+	—	—	1. " "
III.....	2	1	18	76	2.97	o	3+	o	3+	o	3+	o	3+	o	3+	o	3+	+	*30 m.	—	1. " "
IV	4	2	26	70	8.06	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	5 hrs.	1. " "
V......	4	2	22	80	6.58	o	o	o	o	o	1+	o	1+	o	o	o	o	+	†15 "	—	1. " "
VI.. ...	8	4	21	44	12.53	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	5 hrs.	1. " "
VII	8	4	23	82	12.74	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	5 "	1. " "
VIII ...	10	5	23	89	15.50	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 m.	1. 4 layers killed
IX.....	10	5	21	75	22.08	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	2. None killed
X......	16	8	17	66	25.05	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	1. 3 layers killed
XI.....	{ Water, 9 ounces 11	 11	19	73	15.92	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	3. 15 " "
XII	{ Water, 9 ounces 11	 11	18	85	16.15	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	1. None killed
XIII ...	10	7	18	79	16.35	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	1. " "
XIV....	10	7	21	75	22.50	o	o	o	o	o	o	o	o	o	o	o	o	+	†15 "	15 "	3. 2 layers killed

* First culture drawn after starting experiment.

† Second culture drawn after starting experiment.

APPARATUS FOR DISINFECTION.

The Formanganate Disinfector, manufactured by Parke, Davis & Co., Detroit, consists of a 16 fl. oz. bottle of the official Liquor Formaldehyde and a box containing two disks consisting of potassium permanganate, each weighing about four ounces. The outfit is accompanied by directions for use and recommendations for artificially increasing the humidity, as well as other recommendations for the product. The claims made for this preparation are easily substantiated and in the quantity recommended, viz., 16 oz. per 1,000 cu. ft. of space, is undoubtedly efficient. This preparation is practically a duplicate of the formula suggested by McClintic, but the permanganate is in compressed form which causes it to react more slowly than the crystals, and thus eliminates all danger of spattering. A small increase in the formaldehyde obtained after one hour, as compared with the crystals, is pointed out in the manufacturer's circular. This increase also was noticeable in our determinations and is explained, we believe, by the longer time required for the reaction rather than by any increase in the actual amount of gas. The time required to liberate the gas in our experiment was 18 minutes.

DePree's Formaldehyde Fumigator, manufactured by DePree Chemical Co., Holland, Mich., is a solidified formaldehyde having a melting point of about 100° C. and containing a variable proportion of formaldehyde and water, ranging in the samples tested from 62 to 73 per cent formaldehyde. The apparatus consists of a tin box containing the formaldehyde, this being placed over a base containing paraffin having a wick in the center from which the paraffin is burned to evaporate the product. The claim made for this preparation is: "Its efficiency is greater than any of the forms heretofore used, one-half ounce by test being sufficient to thoroughly disinfect 1,000 cu. ft. of space." This preparation is put up in two sizes, No. 0, said to contain one-half ounce for 500 cu. ft. of space, and No. 1, said to contain one ounce for 1,000 cu. ft. of space. Four different lots of these fumigators were examined, the first, consisting of Nos. 1 and 0, was obtained from the general market. The second was obtained from the manufacturers through the Board of Health. The third was taken from a fresh lot at the factory by Secretary Shumway. The fourth was delivered at the laboratory by a representative of the firm for the purpose of these experiments. On examination, these various lots gave the following results:

Lot No.	Size No.	Weight of Product	Formaldehyde Present
1	0	17–18 gm.	66 per cent
1	1	34–35 "	66 " "
2	1	33–35 "	73.2 " "
3	1	35–37 "	63.6 " "
4	1	44–47 "	62.0 " "

All of the samples obtained contained considerably more product than is claimed by the manufacturers, but there seems to be a lack of uniformity both in the amount and formaldehyde strength of the preparations supplied. It is a well-known fact that very small quantities of formaldehyde, under favorable experimental conditions, are capable of destroying certain bacteria, and the claim that one-half ounce in 1,000 cu. ft. of space is sufficient to destroy bacteria is substantiated by our experiments, providing the cultures are moist. On dry cultures, however, this preparation cannot be considered efficient in any of the quantities used in our experiments. Whether further increase in the amount of product would give efficient results on dry cultures was

not determined, because if quantities above 100 gm. per 1,000 cu. ft. are required, the price of this preparation would make its use impractical. Some of the points especially in favor of this preparation are the convenience with which it may be employed and the low melting point, which tends to keep the product evenly distributed in the container until volatilization is complete. Perhaps if artificial moisture can be supplied in a satisfactory manner, this preparation may prove efficient if used in sufficient quantity. The quantity of formaldehyde gas liberated from an average No. 1 DePree candle as obtained in the market is about equivalent to the quantity liberated by three ounces of formalin (40 per cent) when liberated with potassium permanganate, using Hill's 7–10 formula. The time required to evaporate the formaldehyde from a No. 1 candle varied from 35 to 45 minutes.

The International Germ Destroyer, manufactured by International Chemical Co., Chicago, Ill., is a solidified formaldehyde having a melting point of about 170° C. and containing a variable proportion of formaldehyde and water ranging in the samples tested from 57.9 to 69.6 per cent formaldehyde. The apparatus consists of a receptacle of tin containing the product. This container has special provisions for holding added water. The receptacle is placed over a base containing paraffin having a wick in the center from which the paraffin is burned to volatilize the product. This firm claims special efficiency because a certain amount of water is added and volatilized with the formaldehyde. The preparation is put up in five different sizes as follows:

No. 0 said to be sufficient for 1,000 cu. ft.
No. 1 " " " " " 2,000 " "
No. 2 " " " " " 4,000 " "
No. 3 " " " " " 6,000 " "
No. 4 " " " " " 8,000 " "

The amount recommended is one and one-half ounce for each 1,000 cu. ft. of space.

Three different samples were examined, all being obtained directly from the manufacturer, with results as follows:

Lot No.	Size No.	Weight of Product	Formaldehyde Present
1	0	39–41 gm.	57.9 per cent
2	0	38–41 "	69.6 " "
Bulk	2 oz.	58–60 "	67.5 " "

A lack of uniformity in the amount of absolute formaldehyde is again manifest. It is evident that the manufacturer's claim or even the actual weight of the product obtained is at best only a crude approximation to the amount of absolute formaldehyde employed.

The preparation, like others of this type, is commendable for the convenience with which it may be used, and special mention might be made of the added water. Artificial moisture does not materially influence the effect on moist or partially moist cultures in experimental work, but when organisms have been thoroughly dried, artificial moisture is unquestionably of considerable value. This preparation does not melt from the heat of the candle but the gas is given off gradually without the product having melted, requiring somewhat more heat than the preparations with lower melting point, and somewhat more charring of the last portion often results. The quantity of formaldehyde gas liberated from one No. 0 International Germ Destroyer as employed in our experiments is about equivalent to the quantity liberated by three ounces of formalin (40 per cent) by the permanganate method, using Hill's 7–10 formula. The

time required to evaporate the formaldehyde from a No. 0 candle varied from 40 to 50 minutes.

Lister's Fumigator, manufactured by Johnson & Johnson, New Brunswick, N.J., is a solidified formaldehyde having a melting point of about 170° C. and containing over 90 per cent of absolute formaldehyde. The apparatus consists of "a candle of solidified formaldehyde inclosed in a fire proof container in such a way that the candle burns from the bottom upward." In using, the product itself is ignited at the bottom and the heat thus generated volatilizes a portion of the formaldehyde which escapes at the top. These fumigators could be obtained in two sizes, each containing about 25 gm. and 50 gm. of product. No definite amount for a given space is specified, but the accompanying circular recommends "one standard size candle for each room" and double that quantity "where bedding, etc., has been gathered into one room." The manufacturers claim that "lighted at the bottom, the candle generates formaldehyde gas in its most active form, which escapes through the top of the container without passing through the flame, and all of the solidified formaldehyde is converted into the active germ destroying gas." In our experiment, three "standard size" candles were used. Moist cultures were killed but none of the dry cultures were affected. About 75 per cent of the gas was destroyed in the process of liberation, which amount we consider abnormal. No further experiments were conducted with this product because the loss was found too great to render the method of value for practical purposes. The amount of formaldehyde gas furnished by one "standard size" candle is equivalent to about 1½ oz. formalin (40 per cent) when liberated with potassium permanganate, using Hill's 7–10 formula. The time required for the liberation in our experiment was 55 minutes.

Dr. Lowe's Solidified Formaldehyde, manufactured by The Dr. Lowe Formaldehyde Co., Chicago., Ill. is sold in two separate packages, the one containing a formaldehyde powder, the other crystals of potassium permanganate. The two sizes of this preparation were procured in the open market, one said to contain two ounces of formaldehyde, the other, four ounces. The two ounce size was accompanied by one-half pound of potassium permanganate and the four ounce size by one pound of potassium permanganate. The directions called for 40 to 45 ounces of hot water for the two ounce size and from 100 to 110 ounces of hot water for the four ounce size. The four ounce size was said to be sufficient to thoroughly disinfect 9,000 cu. ft. of space. On examination, the two ounce size was found to contain 38 gm. formaldehyde 96.6 per cent pure. The four ounce size was found to contain 77 gm. formaldehyde 96.6 per cent pure. One two ounce size and one four ounce size were used in our experiment together with the accompanying 1½ lb. potassium permanganate. To this was added 150 oz. of boiling water. According to the manufacturer's claims, this should be sufficient "to thoroughly disinfect 14,500 cu. ft. of space" but was employed by us in a relatively tight room of 3,000 cu. ft. The results in Experiment XXVIII can hardly be misinterpreted. A very violent reaction takes place between the permanganate and the formaldehyde, in which about 95 per cent of the formaldehyde is destroyed and the water evaporated. After seeing the chemical results, we were somewhat surprised at the bacteriological findings, which showed many of the cultures to be destroyed and this destruction was manifest in the dry as well as in the moist cultures. This is a marked contrast to some of the preparations liberating dry formaldehyde gas, where often over five times as much gas was found in the air without killing a single dry culture. While this preparation is worthless for practical disinfec-

TABLE 3.

EXPERIMENTS WITH PROPRIETARY ARTICLES.

Experiment Number	Name of Proprietary Preparation	Amount of Preparation Used per 1,000 Cu. Ft.	Temperature ° C.	Humidity Percentage	Amount of Formaldehyde in Mgm. Found per Cu. Ft. of Air Space	Cultural Results: +=Growth, o=No Growth, −=Not Killed in 5 Hrs. 48-Hr. Cultures. Exposed 5 Hrs. Incubation 96 Hrs. Number of Each Exposed, 3 Moist and 3 Dry												B. coli First Culture Killed		Penetration B. coli Dry Culture
						Staphylococci		Streptococci		B. coli		B. diphtheria		B. typhosus		B. anthracis		Control		
						Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry	Dry	Moist	Dry	1 Exposure 5 hrs. 2. Exposure 48 "
XV.....	Formanganate Disinfector	8 oz. Formalin	21	47	12.74	o	o	o	o	o	o	o	o	o	o	o	o	+	*20 m.	5 hrs.	1. None killed
XVI....	DePree's Formaldehyde Fumigator	½ oz.	17	50	2.55	o	3+	o	3+	o	3+	o	3+	o	3+	o	3+	+	† 1 hr.	—	1. " "
XVII...		1 "	18	73	5.09	o	3+	o	3+	o	3+	o	3+	o	3+	o	3+	+	*35 m.	—	1. " "
XVIII..		1⅛ "	27	63	7.64	o	o	o	o	o	o	o	o	o	o	o	o	+	*40 "	—	1. " "
XIX....		1½ "	22	86	7.00	o	o	o	o	o	o	o	o	o	o	o	o	+	*40 "	—	1. " "
XX.....		1½ "	23	65	7.22	o	o	o	o	o	3+	o	2+	o	o	o	o	+	*40 "	—	1. " "
XXI....		2¼ "	23	72	12.10	o	o	o	o	o	o	o	o	o	o	o	o	+	*40 "	—	1. " "
XXII...		3⅛ "	20	56	16.35	o	o	o	o	o	o	o	o	o	o	o	1+	+	*40 "	—	1. " "
XXIII...		3⅓ "	20	81	22.52	o	o	o	o	o	2+	o	o	o	o	o	1+	+	*45 "	—	2. " "
XXIV...	International Germ Destroyer	1¼ "	23	58	6.76	o	1+	o	1+	o	1+	o	3+	o	o	o	o	+	*40 "	—	1. " "
XXV....		2½ "	26	56	11.47	o	o	o	o	o	o	o	o	o	o	o	o	+	* 1 hr.	5 hrs.	1. 2 layers killed
XXVI...	Geo. Leininger's Formulas, Generator	2½ "	23	57	§8.92	o	o	o	o	o	2+	o	o	o	o	o	1+	+	*2 hrs.	—	1. None killed
XXVII..	Lister's Fumigator	1⅝ "	23	40	2.55	o	3+	o	3+	o	3+	o	3+	o	3+	o	3+	+	* 1 hr.	—	1. " "
XXVIII.	Dr. Lowe's Perm. Sol. Form.	1¼ "	26	60	.64	1+	2+	o	1+	2+	3+	1+	2+	o	o	3+	3+	+	—	—	1. " "

*First culture drawn after starting experiment. †Second culture drawn after starting experiment. §Air drawn 2 hrs. after starting experiment.

tion in the proportions recommended, our experience with it serves well to emphasize that oft repeated requirement for successful disinfection which is too often ignored, "An abundance of moisture."

TABLE 4.

SUMMARY OF PROPRIETARY ARTICLES EXAMINED.

Name of Preparation	Manufacturer	Amount Recommended Per 1,000 Cu. Ft.	Absolute Formaldehyde Contained	Method of Liberation	Approximate Loss in Liberation	Efficiency
Formanganate Disinfector	Parke, Davis & Co., Detroit	16 oz.	180 gm.	Permanganate (1–2)	40%	Efficient
DePree's Formaldehyde Fumigator	The DePree Chemical Co., Holland, Mich.	1 oz.	25 gm. Variable	Paraffin Candle	None Variable	Questionable
International Germ Destroyer	International Chemical Co., Chicago	1½ oz.	25 gm. Variable	Paraffin Candle	None Variable	Questionable
Dr. Geo. Leininger's Formaldehyde Generator	International Chemical Co., Chicago	1½ oz.	30 gm. Variable	Alcohol Lamp	None Variable	Questionable
Lister's Fumigator	Johnson & Johnson, New Brunswick, N.J.	Not Stated	45 gm.	Burning Product	75–80%	Inefficient
Dr. Lowe's Solidified Formaldehyde	Dr. Lowe Formaldehyde Co., Chicago	⅛ oz.	8½ gm.	Permanganate	90–95%	Inefficient

The percentage of formaldehyde in the air of the room on successive days seems to have been fairly constant for each method of liberation after a given time but shows considerable variation when influenced by weather changes for longer periods. Thus the percentage of gas recovered from the air after one hour varied during the time of our investigation as follows:

August 12–14—	Permanganate-formalin (1–2).....	13.9 –14.16 per cent
August 17–21—	Permanganate-formalin (1–2).....	17.78 " "
	DePree's Candle.....	30.27 " "
	International Candle.....	29.09 " "
August 24–September 28—	Permanganate-formalin (1–2)).....	13.1 –14.5 " "
	Permanganate-formalin (7–10).....	14.7 " "
	DePree's Candle.....	25.75–26.55 " "
	International Candle.....	21.31 " "
September 30–October 9—	Permanganate formalin (1–2).....	19.5 " "
	Permanganate formalin (7–10).....	19.86 " "
	Permanganate-diluted-formalin Hill's formula.....	12.7 –12.9 " "
	DePree's Candle.....	35 " "

TABLE 5.

SUMMARY OF CHEMICAL RESULTS.

Preparation	Date, 1909	Temperature ° C.	Humidity Percentage	Wind Miles	Formaldehyde Product Used per 1,000 Cu. Ft.	Percentage Strength of Formaldehyde	Method of Liberation	Time Required, Minutes	Time Required to Draw Air	Absolute Formaldehyde Used per 1,000 Cu. Ft. in Gm.	Absorption per Sq. Ft. of Surface in Mgm.		Absolute Formaldehyde Found per Cu. Ft. of Space in Mgm.	Percentage Yield
											Moist	Dry		
Permang.-Form	9/23	17	85	7	15 c.c.	40	$KMnO_4$	5	1 hr., 5 m.	6	11	2	.85	14.10
Permang.-Form	9/28	20	66	15	30 "	37.8	$KMnO_4$	5	1	11	13	2	1.48	13.10
Permang.-Form	9/17	18	76	8	60 "	37.8	$KMnO_4$	5	1	23	15	6	2.97	13.17
Permang.-Form	8/19	26	70	8	120 "	37.8	$KMnO_4$	6	1–20	45	19	11	8.06	17.78
Permang.-Form	8/28	22	80	10	120 "	37.8	$KMnO_4$	6	1–10	45	23	11	6.58	14.51
Permang.-Form	8/12	21	44	2	240 "	37.8	$KMnO_4$	7	1–40	91	..	..	12.52	13.90
Permang.-Form	8/26	23	82	6	240 "	37.8	$KMnO_4$	6	1–15	91	45	22	12.74	14.04
Permang.-Form	9/14	23	89	21	300 "	37.8	$KMnO_4$	6	1	113	29	19	15.50	13.67
Permang.-Form	10/7	21	75	6	300 "	37.8	$KMnO_4$	6	1	113	39	25	22.08	19.50
Permang.-Form	8/24	17	66	14	480 "	37.8	$KMnO_4$	6	1–15	171	63	43	25.05	13.80
Permang.-Dilut.-Formalin	10/2	19	73	4	330 "	37.8	$KMnO_4$	6	1	125	35	30	15.92	12.77
Permang.-Dilut.-Formalin	9/30	18	85	1	330 "	37.8	$KMnO_4$	6	1	125	53	24	16.15	12.96
Permang.-Form	9/25	18	79	18	300 "	37.8	$KMnO_4$	6	1	113	55	39	16.35	14.70
Permang.-Form	10/5	21	75	1	300 "	37.8	$KMnO_4$	6	1	113	45	27	22.50	19.86
Formanganate	8/14	21	47	7	240 "	37.8	$KMnO_4$	18	1–30	90	35	19	12.74	14.16
DePree's Candle	9/20	17	50	7	16 gm.	62	Paraffin Candle	30	1–10	10	22	6	7.64	30.27
DePree's Candle	9/21	18	73	11	31 " "	62	" "	35	1–5	19	38	10	5.10	26.51
DePree's Candle	8/19	27	63	8	34.5 " "	73	" "	38	1–30	25	16	6	7.64	30.27
DePree's Candle	9/2	22	89	3	44 " "	62	" "	40	1–10	27	26	11	7.00	25.88
DePree's Candle	9/1	23	65	7	45 " "	62	" "	40	1–20	28	32	11	7.22	25.75
DePree's Candle	8/31	23	72	4	72 " "	63.6	" "	40	1–55	46	48	19	12.10	26.55
DePree's Candle	9/18	20	56	6	100 " "	62	" "	40	1–15	62	54	20	16.35	26.37
DePree's Candle	10/9	20	81	4	104 " "	62	" "	44	1	64	40	19	22.52	35.00
Leininger's Candle	8/21	23	58	2	40 " "	57.9	" "	47	1–20	23	21	9	6.79	29.09
Leininger's Candle	9/4	26	56	5	77 " "	69.6	" "	45	1–20	54	28	17	11.47	21 31
Alcohol Lamp	9/7	23	57	3	77 " "	67.5	Alcohol Lamp	1–45	1–30	52	40	18	8.92	17.08
Lister's	9/9	23	40	2	50 " "	91	Burning Product	55	1–5	45	9	2	2.55	5.60
Dr. Lowe's	9/11	26	60	7	38 " "	96.6	$KMnO_4$	4	1–15	37	1	1	.64	1.72

The amount of gas recovered after one hour does not seem to have been materially affected by wind movements and the rate of leakage was about the same on a quiet as on a windy day. The amount of formaldehyde in the air of the room is practically in inverse proportion to the amount absorbed by the exposed surfaces, and if these surfaces be moist or contain a good deal of moisture, a larger proportion of the gas is absorbed than when the walls are dry and consequently less formaldehyde will be recovered from the air. An open vessel containing distilled water one-half inch in depth was found after 5 hrs. in Exp. XIII to have absorbed formaldehyde at the rate of 1.2 gm. per sq. ft. of surface.

CULTURAL RESULTS.

Abnormal variations in cultural results are to be expected, and no attempt should be made to interpret these except in a broad general way. McClintic[1] concludes "that in surface disinfection with formaldehyde, the organisms are mostly killed within the first hour of exposure if they are destroyed at all." In practical work it is not probable that any amount of formaldehyde which requires more than two hours for destruction is to be depended upon, for the rate of leakage from the average room in that time will have reduced the quantity of gas to a point where very little action can be expected. The rapid reduction in the quantity of gas present noted by McClintic, however, was probably due more to absorption than to leakage. It is a curious fact that the various proprietary manufacturers have in their possession testimonials and recommendations from numerous bacteriologists showing the efficiency of their product, and many of these bacteriologists are peculiarly men of national or international reputation. But the methods of investigation and the nature of the culture as well as the conditions of exposure vary so enormously that such testimonials are practically worthless. Dr. C. A. Marshall says: "To my mind, a silk thread that has just been moistened in the culture and exposed means very little. We are contending largely with desiccated forms, and when we come to the matter of determining the value of disinfectants in connection with desiccated forms, it has been

[1] *Hygiene Laboratory Bull. No. 27*, 1906.

my experience that there is no uniformity of results. For instance, I find that a thread that has been dried 24 hours will give quite different results than one that has been dried 72 hours." We have shown that a moist surface can absorb in thirty minutes 450 mgm. of formaldehyde per sq. ft., while a dry surface absorbed only 35 mgm. under the same conditions. The effect upon cultures is practically proportionate to the amount of moisture present. McClintic says: "The rôle played by the relative humidity in formaldehyde disinfection is more important than that of any other influencing factors. In the absence of moisture, formaldehyde is practically inert as a germicide." But he concludes that artificial moisture does not answer the purpose so well as the natural humidity of the atmosphere. McClintic however worked with cultures dried one hour, which are in reality moist cultures. Had he worked with thoroughly dried cultures, his conclusions would undoubtedly have been different. In our experiments, where 10 oz. or above of formalin was liberated by permanganate, the room became hazy with water vapor and invariably the B. coli cultures drawn after 15 minutes were incapable of growth. This water vapor we believe acted upon the cultures partially as did the distilled water used in the moist cultures. Dry cultures drawn into the room after it became clear were not killed even with much longer exposure. The result of our penetration experiments is highly unsatisfactory and no definite conclusions can be drawn. It would seem that formaldehyde cannot be depended upon for any marked degree of penetration and neither is there any special advantage in prolonging the exposure to more than eight or ten hours. The bacteriological tests used in each experiment given were duplicated by practical disinfection of two private houses and one suite of offices, using McClintic's (1–2) formula and 10 oz. for-formalin for each 1,000 cu. ft. of space. In the office all cultures were killed exposed in different parts and the cultures in the penetration pad were killed after 30 hours through the fifteenth layer. In one of the houses five cultures under the first seven layers were killed, the remainder growing freely. In the other house with the penetration pad exposed in a bedroom none of the cultures in the pad were killed after 24 hours' exposure, but all cultures openly exposed showed no growth.

After considering the results of these experiments, we cannot but be impressed by the important advice of Werner[1] when he says:

1. The strength of the formaldehyde used should be known.

2. In exceptional cases, where numerous objects or a good deal of organic matter are present or where loss of formaldehyde cannot be avoided, the quantity of formaldehyde should be doubled.

It has been argued that under certain conditions a small amount of formaldehyde is sufficient. Such arguments are easily borne out by experimental evidence. In practical work, however, we are not dealing with certain conditions but with average conditions. It is evident that very small quantities of formaldehyde are sufficient to kill moist cultures of bacteria suspended in the air, but what practical value has this knowledge? Chapin has intimated that aerial disinfection is a myth and this idea is not without substantial foundation. Numerous able experimenters have shown the absence of specific pathogenic organisms from the air except as they are carried by floating particles of dust or other solid material. Bacteria are not winged insects flying through space, but solid bodies which fall by virtue of their own gravity. The surgeon gives little heed to the air which floats around his incision. But no skilled operator will plunge an instrument into his wound unsterilized, after dropping it on the floor. It is safe to estimate that one square inch of floor surface contains more bacteria under average conditions than the air of the entire room. Let us then turn our attention to the surfaces and be less considerate of the space. Surface disinfection is not a myth as can be easily demonstrated in the case of many infectious diseases. Rickards[2] has shown that B. tuberculosis may remain alive in sputum for at least three months. We have found B. diphtheria alive in membranes at room temperature after 48 days, and other observers have reported even longer periods. The virus of other infectious diseases has been shown to retain its virulence for a considerable period. The organisms to be reached in practical surface disinfection are not moist cultures suspended in mid-air, but organisms that have been dried for days or weeks, inclosed in whatever organic discharges they may have been excreted. Therefore the quantity of formaldehyde

[1] *Archiv f. Hyg.*, 1904, 50, p. 305.

[2] *Amer. Jour. Pub. Hyg.*, 1909, 19, p. 586.

must be sufficient to destroy thoroughly dried organisms and must possess sufficient penetrating power to reach them.

Formaldehyde has a powerful avidity for water. In the absence of water, even enormous quantities of formaldehyde exert but little influence. It has been argued that natural humidity only is of value at the time of disinfection and that artificially supplied moisture does not materially aid the efficiency of formaldehyde. For short exposures this is probably true. The high humidity we believe has only an indirect value in that it increases the amount of moisture in and on the objects to be acted upon, and with the increased moisture correspondingly more formaldehyde is absorbed.

What should be required for efficient room disinfection? Rickards says: "The amount of work involved in a proper solution of the problem is enormous, more than one man or a few men can hope to do."

McClintic concludes: "Formaldehyde gas, regardless of the method by which it is evolved, is a powerful surface disinfectant under certain conditions. Successful disinfection with it is so dependent upon several factors that its usefulness is more or less limited. The temperature and humidity are of primary importance, while the influence of the winds, character of the room, etc., are of secondary importance. A small quantity of formaldehyde is efficient for surface disinfection, provided the temperature and humidity are high. A large quantity assists penetration as also do high temperature and humidity, but even then the penetrating power of formaldehyde is so limited that it should not be employed for disinfection purposes requiring any marked degree of penetration. Depending upon the conditions as stated, the quantity of formalin may vary from 200 c.c. to 500 c.c. per 1,000 cu. ft. of air space." "For simplicity and rapidity the formalin-permanganate method is far superior to any other methods tried. It liberates the formaldehyde gas almost instantaneously and in almost as large a quantity as the retort and autoclave methods. The formalin-permanganate method is more applicable than any of the other methods for disinfecting an inclosure which is not comparatively tight."

For the purpose of ascertaining the methods recommended by other states, a circular letter, asking for information on various points,

was addressed to the secretary of the various state boards of health. Answers to this circular letter have up to the present time been received from 30 state boards of health, which answers are summarized as follows:

Formaldehyde disinfection is recommended by 29.

One does not believe in room disinfection.

Of the 29 which employ formaldehyde, 27 recommend the permanganate-formalin method, two recommed the retort method, injecting 1 lb. of formalin per 1,000 cu. ft. of space.

One uses the autoclave occasionally and three permit the use of solidified formaldehyde, one of these recommending the DePree candle in double the quantity recommended by the manufacturer, together with artificial moisture, the other two not specifying the method of liberating the gas.

One board considers the solid proprietary products all right for surface disinfection but does not believe they furnish sufficient penetration. Some of the boards are very emphatic in denouncing proprietary preparations. Artificial moisture is recommended by 24, and not recommended by 5, one considering it of questionable value.

In determining quantity, 24 consider space only, 5 consider surface as well as space, one believing this to be all important. Three increase the quantity when the temperature is below 60° F.

Among those recommending the permanganate-formalin method, four use 32 oz., one uses 20 oz., eighteen use 16 oz., three use 11 oz., and one uses 10 oz. per 1,000 cu. ft. of space.

The formulae employed for each 1,000 cu. ft. are as follows:

Permanganate 13 oz., Formalin 32 oz.—Four
Permanganate 7½ oz., Formalin 20 oz.—One
Permanganate 8 oz., Formalin 16 oz.—Seven
Permanganate 7½ oz., Formalin 16 oz.—Three
Permanganate 6¾ oz., Formalin 16 oz.—One
Permanganate 6½ oz., Formalin 16 oz.—Three
Permanganate 4 oz., Formalin 16 oz.—Two
Permanganate 3½ oz Formalin 16 oz.—One
Permanganate not stated, Formalin 16 oz.—One
Permanganate 11 oz., Water 9 oz., Formalin 11 oz.—Two
Permanganate 9 oz., Water 11 oz., Formalin 11 oz.—One
Permanganate 4 oz., Formalin 10 oz.—One

From the above replies we must conclude that the methods employed by the states are somewhat more satisfactory than in the cities investigated by Rickards, there being only one state which recommends a proprietary article of solidified formaldehyde and that being in not less than two ounce quantities. Two other states, however, recognize solidified formaldehyde without specifying method of liberation. This is very unsatisfactory, for, as we have seen, the

liberation of solidified formaldehyde may be by methods having little or no loss to a loss of 95 per cent of the product. We do not consider it necessary to buy the liquid preparation on analysis, for Liquor Formaldehyde is official in the U.S. Pharmacopoea and must contain at least 37.5 per cent formaldehyde. We made no inquiry concerning test cultures as a routine procedure in disinfection for we do not consider such tests as carried out by the average disinfector reliable, and the results that have been thus obtained are practically a worthless addition to our literature. The proportions of permanganate to formalin recommended by the various states is interesting, and employed as given, the amount of formaldehyde lost will vary from about 40 per cent with the 8 to 16 formula to about 75 per cent with the $3\frac{1}{2}$ to 16 formula. If the states using the lower proportions of permanganate would occasionally examine the residues remaining in the pail after a disinfection, they could hardly fail to appreciate the importance of increasing the permanganate. Any formula containing less than one part by weight of permanganate to two parts by volume of formalin is surely uneconomical, and with the present market values of formalin and permanganate the 7 to 10 formula of Hill is highly commendable.